(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 710 923 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.05.1996 Bulletin 1996/19

(51) Int. Cl.^{6}: G06K 19/06

(21) Application number: 95117166.9

(22) Date of filing: 31.10.1995

(84) Designated Contracting States:
DE ES FR GB IT

(30) Priority: 02.11.1994 JP 269481/94
13.10.1995 JP 265282/95

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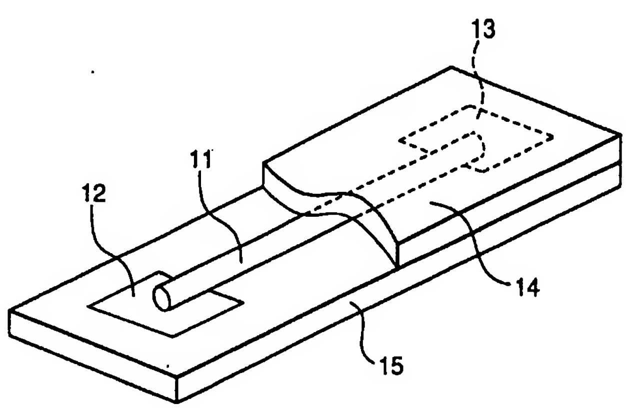
(54) Magnetic marker

(57) A magnetic marker of the invention comprises a magnetic thin wire for generating pulses and soft magnetic materials having a smaller coercive force than the magnetic thin wire, the bodies are arranged close to the two ends of the thin wire. The magnetic thin wire has a diameter of 60-115 μm and has a ratio of B_r/B_s of BH loop of 0.8 or more. Thus, a small magnetic marker can be provided which shows large Barkhausen effect even if it has a very short magnetic thin wire.

Fig. 1



EP 0 710 923 A2

Printed by Rank Xerox (UK) Business Services
2.11.6/3.4

Description

The present invention relates to a magnetic marker attached to a good for detecting the existence thereof.

It is known to attach markers to goods to detect a number and kind of goods or to prevent theft. Such markers are attached to a good so that the marker cannot be noticed readily, and they are detected with magnetic properties or microwaves.

There are various kinds of such markers. For example, if an amorphous thin ribbon or thin wire as a marker is subjected in an AC magnetic field, disturbance in magnetic field in a scan area or harmonic components of an output pulse thereof can be detected. If another example of a marker comprising a coil and a capacitor made of aluminum is subjected to radiation of electric waves, LC resonance can be detected. Among the markers, there is a magnetic marker having large Barkhausen characteristic, and sharp pulses generated on magnetization reversal can be detected under an AC magnetic field. It has advantages that it has a high sensitivity, a light weight and causes less erroneous detections.

Large Barkhausen reversal is a phenomenon caused by movement of magnetic domains in a material, and it occurs when a limit magnetic field H^* needed to generate inverse magnetic domains is larger than a minimum magnetic field H_0 needed to move magnetic domains. Inverse magnetic domains are formed when an effective magnetic field H_{eff} which is equal to an external magnetic field H_{ex} subtracted by a demagnetizing field H_d generated at the magnetic thin wire by the external magnetic field H_{ex} exceeds the limit magnetic field H^*, and at the same time they moves instantly to generate a sharp magnetization reversal. It is a characteristic that an output induced voltage accompanied by the magnetization inversion is constant irrespective of the external magnetic field and a speed of change in magnetic field and that it has a sharp pulse waveform having high harmonic components.

Among such magnetic markers, a marker disclosed in Japanese Patent laid open Publication 4-195384/1992 has a structure that soft magnetic materials having a low coercive force are arranged at two ends of a magnetic thin wire for generating pulses. The magnetic thin wire shows large Barkhausen effect, and the two soft magnetic materials have a coercive force H_c smaller than that of the magnetic thin wire. The demagnetizing field of the magnetic thin wire for generating pulses is reduced by the soft magnetic materials arranged close to the magnetic bar. Then, the magnetic marker can be made compact.

Because the magnetic thin wire of the magnetic marker has a diameter of 120 µm, if the length of the magnetic thin wire is as short as 50 mm or less, good large Barkhausen effect cannot be generated, and a practically large output voltage cannot be obtained. However, it is desirable for a magnetic marker to shorten the length thereof more to make it more compact.

An object of the invention is to provide a small magnetic marker showing large Barkhausen reversal and a very short length thereof.

A magnetic marker according to the invention for generating a large Barkhausen effect comprises a magnetic thin wire for generating pulse signals, and two magnetic plates having a coercive force smaller than that of the magnetic thin wire. The magnetic thin wire has a diameter of 60-115 µm and has a rectangular ratio B_r/B_s of BH loop of 0.8 or more. The magnetic marker generates large Barkhausen effect in a magnetic field to generate pulses induced in a coil for detection.

A feature of the invention is that the magnetic marker comprises a combination of the magnetic thin wire for generating pulse signals and the magnetic materials for reducing a demagnetizing field. The magnetic materials have a coercive force smaller than that of the magnetic thin wire and are arranged closely at the two ends of the magnetic thin wire, so that they reduces the demagnetizing field of the magnetic thin wire. Therefore, even if the magnetic thin wire is short and large Barkhausen reversal is not observed because of large demagnetizing field when only the magnetic thin wire were used as a marker, the magnetic marker including the same magnetic thin wire can induce pulses in a coil so as to generate excellent induced voltage by large Barkhausen effect.

The magnetic thin wire for generating pulses has a diameter in a range of 60 to 115 µm and has 0.8 or more of a rectangular ratio B_r/B_s of BH loop or magnetization curve, where B_r denotes a remanent magnetic flux under zero external magnetic field and B_s denotes a saturation magnetic flux when magnetization saturates. If the rectangular ratio B_r/B_s of the magnetic thin wire is 0.8 or more, high pulse electric voltages suitable for a marker can be generated. If the diameter (cross section) of the magnetic thin wire becomes smaller, the demagnetizing field of the magnetic thin wire can be reduced, and the length of the magnetic thin wire can be shortened in accordance to the reduction of the cross section of the magnetic thin wire. The invention makes it possible to provide a compact magnetic marker without deteriorating excellent induced voltage by large Barkhausen effect (pulse voltage values and harmonic components).

Even if the rectangular ratio B_r/B_s of the magnetic thin wire is 0.8 or more, the demagnetizing field becomes large when the diameter thereof is larger than 115 µm, or the total magnetic flux becomes small when the diameter is smaller than 60 µm. Then, excellent induced voltage by large Barkhausen effect cannot be generated. Even if the rectangular ratio B_r/B_s of the magnetic thin wire is smaller than 0.8, large Barkhausen reversal does not occur when the diameter thereof is large, or the total magnetic flux becomes small when the diameter is small though large Barkhausen reversal occurs. Then, excellent induced voltage by large Barkhausen effect for a magnetic marker cannot be generated. The length of the magnetic thin wire is preferably 10-100 mm, more preferably 15-50 mm.

The two magnetic materials of the invention is needed to have a coercive force smaller than that of the magnetic thin wire, and it is preferable to use a magnetic sheet (magnetic thin plate) having a coercive force smaller than that of the magnetic thin wire. The coercive force of the magnetic thin wire means a value measured for a sample having a length of 100 times the diameter thereof or longer, and the coercive force of the magnetic materials means a value measured for a sample having a length larger than 100 times the thickness thereof or longer.

The magnetic sheet of the invention refers to a sheet having a thickness of 0.01 - 100 µm and an area of 1 - 10,000 mm². If the magnetic sheet has a length of 100 times the thickness thereof or longer, a various shape such as circle, ellipse or polygon may be adopted for the magnetic sheets as far as the coercive force thereof is smaller than that of the magnetic thin wire. A rectangular magnetic sheet is most preferable as to the reduction of the demagnetizing field of the magnetic bar.

As to the relative position of the magnetic thin wire and the magnetic sheets, the demagnetizing field of the magnetic thin wire is reduced largest if the ends of the magnetic thin wire are located at the center of the magnetic sheets.

An advantage of the invention is to provide a very small magnetic marker having a high output voltage and large harmonic components due to large Barkhausen effect.

These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, and in which:

Fig. 1 is a schematic perspective, partially exposed view of a magnetic marker of first to sixth examples of the invention;
Fig. 2 is a graph of a gain of 30th harmonic wave of examples and a comparison example plotted against the length of the magnetic thin wire;
Fig. 3 is a graph of an induced voltage of the examples and the comparison example plotted against the length of the magnetic thin wire;
Fig. 4 is a graph of a gain of 30th harmonic wave plotted against the position of the end of the magnetic thin wire for generating pulses;
Fig. 5 is a graph of electromagnetic induction voltage plotted against the position of the end of the magnetic thin wire for generating pulses;
Fig. 6 is a schematic plan view of a magnetic marker of a seventh example of the invention; and
Fig. 7 is a schematic plan view of a magnetic marker of an eighth example of the invention.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, embodiments of the present invention will be explained with reference to appended drawings according to examples.

In general, in order to produce a compact magnetic thin wire, it is needed to shorten the length of a magnetic thin wire for generating pulses. However, if a ratio (aspect ratio) of a length to a diameter of the magnetic thin wire is reduced, the demagnetizing field of the magnetic thin wire increases, and excellent induced voltage by large Barkhausen effect cannot be generated by using a coil for detection. Further, an output electric voltage induced in the coil depends on the total magnetic flux changed, if the length and the diameter of the magnetic thin wire are decreased under the same aspect ratio, a signal-to-noise ratio of the magnetic marker decreases, and a good magnetic marker cannot be provided.

The magnetic thin wire of the invention for generating pulses is needed to have 60-115 µm of diameter and 0.8 or more of a rectangular ratio B_r/B_s of BH loop. In order to produce a magnetic marker of high performance, it is required to reduce the size of the magnetic thin wire to decrease the demagnetizing field while increasing the total magnetic flux subjected to the magnetic reversal.

An amorphous magnetic thin wire having magnetostriction of an absolute value of $1*10^{-6}$ or more is preferable for the magnetic thin wire with a small diameter and 0.8 or more of a rectangular ratio B_r/B_s. It is fabricated by cold wire drawing process according to a conventional drawing process of a metallic thin wire and a thermal treatment after the drawing. The drawing of the magnetic thin wire can be performed in a reduction ratio of cross section of 5-15 % with a dice, and the drawing up to a desired diameter can be attained by using a plurality of dices. The thermal treatment for the magnetic thin wire having a diameter in the above-mentioned range can be performed under tensile strength of 10-250 kg/mm² at a temperature of 300-500 °C for a period in a range of 0.1 to 1000 seconds, to result in a magnetic thin wire having desired magnetic characteristics. The following explanation relates to examples using rectangular magnetic sheets (magnetic thin plates) in magnetic markers having the magnetic thin wire having large Barkhausen effect and the magnetic sheets (magnetic thin plates) arranged close to the magnetic bar. However, the invention can also be applied to combinations of the magnetic thin wire with various shapes of the magnetic sheets.

First, magnetic markers of first to sixth examples of the invention are explained. Fig. 1 shows the magnetic marker of the examples schematically. The magnetic marker comprises a magnetic thin wire 11 as an element for generating pulses and two rectangular magnetic sheets 12 and 13 arranged close to two ends of the magnetic thin wire 11, and they are interposed between base materials 14 and 15 for fixing them. The material and the thickness of the base materials 14 and 15 are variable according to applications of the magnetic marker. Usually, the base materials 14, 15

are polyethylene telephthalate (PET) film adhesion sheets having a thickness of about 30 μm. The base material 15 has an adhesion layer (not shown) at the bottom for attaching the magnetic marker to a good to be detected. On the other hand, an adhesion layer (not shown) at the top of the base material 15 at the top for fixing the magnetic thin wire 11 and the magnetic sheets 12 and 13 thereto and adhering the other base material 14 to them. In the arrangement of the magnetic thin wire 11 and the magnetic sheets 12 and 13, the two ends of the magnetic thin wire 11 are preferably located at positions (centers) having equal distances from each side of the magnetic sheets 12 and 13, as shown in Fig. 1. For example, the magnetic sheets 12 and 13 have a square shape with a side of 10 mm, and its thickness is 20 μm.

First to sixth examples with a shape shown in Fig. 1 having various diameters and rectangular ratio B_r/B_s are produced, and first to fifth comparison examples are produced similarly, as compiled in Table 1.

Fig. 2 shows a relation of the length of the amorphous magnetic thin wire 11 to harmonic components of output pulses in the magnetic marker shown in Fig. 1. In the magnetic marker of the third example, the magnetic thin wire is a Co-Fe amorphous magnetic thin wire having a diameter of 99 μm, a rectangular ratio B_r/B_s of 0.93 and a coercive force of 0.25 Oe, while in the magnetic marker of the sixth example, the magnetic thin wire is a Co-Fe amorphous magnetic thin wire having a diameter of 74 μm, a rectangular ratio B_r/B_s of 0.95 and a coercive force of 0.35 Oe. On the other hand, in the magnetic marker of the first comparison example, the magnetic thin wire is a Co-Fe amorphous magnetic thin wire having a diameter of 125 μm, a rectangular ratio B_r/B_s of 0.5 and a coercive force of 0.12 Oe. The data of the third and sixth examples are displayed with solid circles and solid squares, while the data of the first comparison example are displayed with circles. The coercive force is measured on a thin wire of length of 15 cm in an excitation magnetic field of 1 Oe and frequency of 50 Hz. In the two examples and the comparison example, the magnetic sheets 12 and 13 are Co-based amorphous ribbon with a square shape of a side of 10 mm and thickness of 20 μm. The coercive force of the magnetic sheets measured in an excitation magnetic field of 1 Oe at a frequency of 50 Hz is 0.03 Oe. The rectangular ratio B_r/B_s is measured on an amorphous magnetic thin wire sufficiently long so as not to be affected by the demagnetizing field.

The magnetic marker is magnetized in an alternating magnetic field of amplitude of 1 Oe at a frequency of 50 Hz, and an induction voltage is detected with a coil of a length of 35 mm and a winding number of 590 turns. The induced voltage in the coil is analyzed and evaluated with a dynamic signal analyzer of Hewlett Packard type 3562A. It can be decided by measuring a gain of 30th harmonic component of excitation frequency if a marker generates excellent induced voltage by large Barkhausen effect. It is desirable for a magnetic marker using large Barkhausen effect to have a gain of -53 dB or more of the 30th harmonic component for a reference signal of 1 V. The measurement data on the sixth example (solid squares) show that magnetic markers with the magnetic thin wire as short as 15 mm has good harmonic gain. On the other hand, in the comparison example, good harmonic gain cannot be obtained if the length of the magnetic thin wire is not 50 mm or longer.

Fig. 3 shows a characteristic of output voltage (e_p) induced in the coil plotted against the length of the magnetic thin wire of the magnetic markers used in the measurement shown in Fig. 2. The data of the third and sixth examples are displayed as solid circles and solid squares, while the data of the first comparison example are displayed as circles. In the magnetic markers of the sixth example (solid squares), large Barkhausen effect of output voltage of 100 mV or more can be generated even if the length of the magnetic thin wire 11 is as short as 15 mm. On the other hand, in the comparison example, good output voltage cannot be generated if the length of the thin wire is not 50 mm or more.

Table 1 summarizes output voltage and 30th harmonic component of magnetic markers having the length of the magnetic markers of 25 mm and with magnetic thin wire of various diameters and rectangular ratio B_r/B_s.

In Table 1, the coercive force of each magnetic thin wire is 0.1-0.3 Oe when measured on a thin wire of length of 10 cm in an excitation magnetic field of 1 Oe at a frequency of 50 Hz.

Table 1

	diameter (μm)	B_r/B_s	induced voltage (mV)	30th harmonic components (dB)
Example No. 1	109	0.82	113	-50.1
2	104	0.87	121	-50.8
3	99	0.93	140	-51.0
4	92	0.91	132	-51.4
5	88	0.88	134	-52.1
6	74	0.95	120	-52.5
Comparison Example No. 1	125	0.50	13	-74.3
2	120	0.95	30	-60.5
3	50	0.95	60	-57.0
4	125	0.63	10	-90.0
5	70	0.75	20	-70.0

As is clear from Table 1, induced voltage by large Barkhausen effect having a sufficiently large output voltage and 30th harmonic component can be generated for the magnetic thin wire 11 having a diameter of 74-110 μm and has a ratio of B_r/B_s of 0.8 or more. On the other hand, as shown as comparison examples in Table 1, if the diameter is 125 μm and the rectangular ratio B_r/B_s is 0.5, large Barkhausen reversal does not occur, and the output voltage and the 30th harmonic component are small. Even for magnetic thin wires with the rectangular ratio B_r/B_s is 0.9 or more, if the diameter is 120 μm, the demagnetizing field becomes large, or if the diameter is 50 μm, the total magnetic flux to be reversed is small. Therefore, excellent induced voltage by large Barkhausen effect cannot be produced in the two cases. If magnetic thin wires with the rectangular ratio B_r/B_s is less than 0.8, large Barkhausen reversal does not occur, and the good output voltage and the 30th harmonic component as a magnetic marker cannot be generated.

The advantages of the magnetic marker of the invention are not deteriorated even if the size (area) of the two magnetic thin plates 12 and 13 arranged close to the magnetic thin wire is large. However, if the area of the magnetic thin plates 12, 13 becomes large, the magnetic marker cannot be produced compactly.

Next, relative location of the ends of the magnetic thin wire 11 to the magnetic sheets 12 and 13 to be arranged close thereto is explained. The magnetic thin wire 11 of the third example having a length of 25 mm is used, while magnetic sheets 12 and 13 have a thickness of 20 μm and a side of square of 10 mm. Figs. 4 and 5 show the 30th harmonic gain and the output voltage of the magnetic marker at various positions of the ends of the magnetic thin wire on the magnetic sheets 12 and 13. The abscissa represents the position of the end of the magnetic thin wire along longitudinal direction (solid circles or black circles) and along width direction (circles or white circles) as a distance from each side. The positions where excellent induced voltage by large Barkhausen effect is generated are described below. Along the longitudinal direction of the magnetic marker, it is desirable that the end thereof exists around the center of the magnetic sheet 12, 13 within ±25% from the center as to a ratio relative to the length of the sheet along the longitudinal direction, and within ±25% from the center as to a ratio relative to the length of the sheet along the width direction.

In order to decrease the demagnetizing field of the magnetic thin wire for generating pulses, the magnetic marker of the invention may use various shapes of the magnetic sheets other then a square as the magnetic plates arranged close to the ends of the magnetic thin wire. Even if the shape of the magnetic sheets 12 and 13 is other than a rectangle, it is desirable that the end of the magnetic thin wire exists within ±25% from the center of the magnetic sheet along the longitudinal direction and along the width direction.

Next, a seventh example is explained. As shown in Fig. 6, circular magnetic sheets are used as the magnetic plates. The magnetic marker comprises a magnetic thin wire 111 as an element for generating pulses and two circular magnetic sheets 112 and 113 arranged close to two ends of the magnetic thin wire 111, and they are interposed between base materials (not shown) for fixing them, similarly in the first embodiment shown in Fig. 1. Preferably, the two ends of the magnetic thin wire 111 are positioned at the centers of the circular magnetic sheets 112 and 113. In concrete, the length of the magnetic thin wire 111 is 25 mm, and the diameter thereof is 99 μm. The rectangular ratio B_r/B_s is 0.93, and the coercive force is 0.25 Oe. On the other hand, the circular magnetic sheets 112 and 113 have a thickness of 20 μm, a diameter of 10 mm and a coercive force of 0.03 Oe.

The output voltage and 30th harmonic component of the magnetic marker is measured similarly to the first embodiment. The output voltage is 125 mV, and the 30th harmonic component is -52 dB. Thus, excellent induced voltage by large Barkhausen effect can be obtained.

Next, an eighth example is explained. As shown in Fig. 7, triangular magnetic sheets having three equal sides are used as the magnetic plates. The magnetic marker comprises a magnetic thin wire 211 as an element for generating pulses and two triangular magnetic sheets 212 and 213 arranged close to two ends of the magnetic thin wire 211, and they are interposed between base materials (not shown) for fixing them, similarly in the first embodiment. Preferably, the two ends of the magnetic thin wire 211 are positioned at the centers of the triangular magnetic sheets 212 and 213. In concrete, the length of the magnetic thin wire 211 is 25 mm, and the diameter thereof is 99 µm. The rectangular ratio B_r/B_s is 0.93, and the coercive force is 0.25 Oe. On the other hand, the triangular magnetic sheets 212 and 213 have a thickness of 20 µm, a side of the rectangle of 10 mm and a coercive force of 0.03 Oe.

The output voltage and 30th harmonic component of the magnetic marker is measured similarly to the first embodiment. The output voltage is 114 mV, and the 30th harmonic component is -52.4 dB. Thus, excellent induced voltage by large Barkhausen effect can be obtained.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

Claims

1. A magnetic marker showing large Barkhausen effect, the magnetic marker comprising:
   a magnetic thin wire generating pulse signals; and
   two magnetic materials having a coercive force smaller than that of the magnetic thin wire, two ends of said magnetic thin wire being arranged close to said two magnetic materials;
   wherein said magnetic thin wire has a diameter of 60-115 µm and has 0.8 or more of a rectangular ratio B_r/B_s of BH loop.

2. The magnetic marker according to Claim 1, wherein said magnetic thin wire is made of an amorphous magnetic material.

3. The magnetic marker according to Claim 1 or 2, further comprising first and second base layers fixing said magnetic thin wire and said two magnetic materials between said first and second base layers.

4. The magnetic marker according to Claim 3, wherein said base layers are made of polyethylene telephthalate film.

5. The magnetic marker according to any one of Claims 1 to 4, wherein said magnetic materials are made of a magnetic sheet having a thickness of 0.01 - 100 µm and an area of 1-10,000 mm^2.

6. The magnetic marker according to any one of Claims 1 to 5, wherein said magnetic materials are made of a square magnetic sheet.

7. The magnetic marker according to any one of Claims 1 to 5, wherein said magnetic materials are made of a circular magnetic sheet.

8. The magnetic marker according to any one of Claims 1 to 5, wherein said magnetic materials are made of a triangular magnetic sheet.

9. The magnetic marker according to any one of Claims 1 to 8, wherein two ends of said magnetic thin wire are positioned at a position within 25% from a center of each magnetic material along a longitudinal direction of said marker.

10. The magnetic marker according to any one of Claims 1 to 9, wherein two ends of said magnetic thin wire are positioned at a position within 25% from a center of each magnetic material along a width direction of said marker.

11. The magnetic marker according to Claim 10 wherein two ends of said magnetic thin wire are positioned at a center of each magnetic material .

Fig. 1

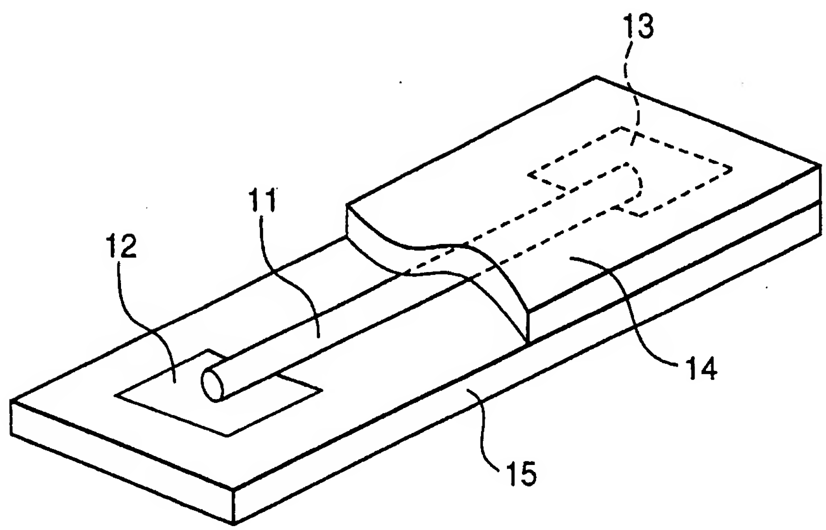


Fig.2

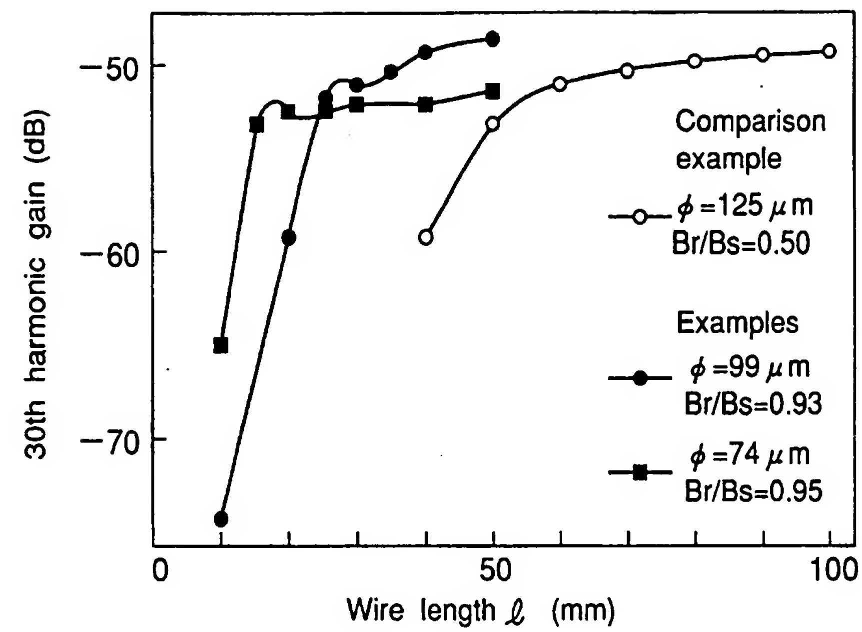

−50
−60
−70
30th harmonic gain (dB)
0
50
100
Wire length ℓ (mm)
Comparison example
ϕ =125 μm
Br/Bs=0.50
Examples
ϕ =99 μm
Br/Bs=0.93
ϕ =74 μm
Br/Bs=0.95

Fig.3

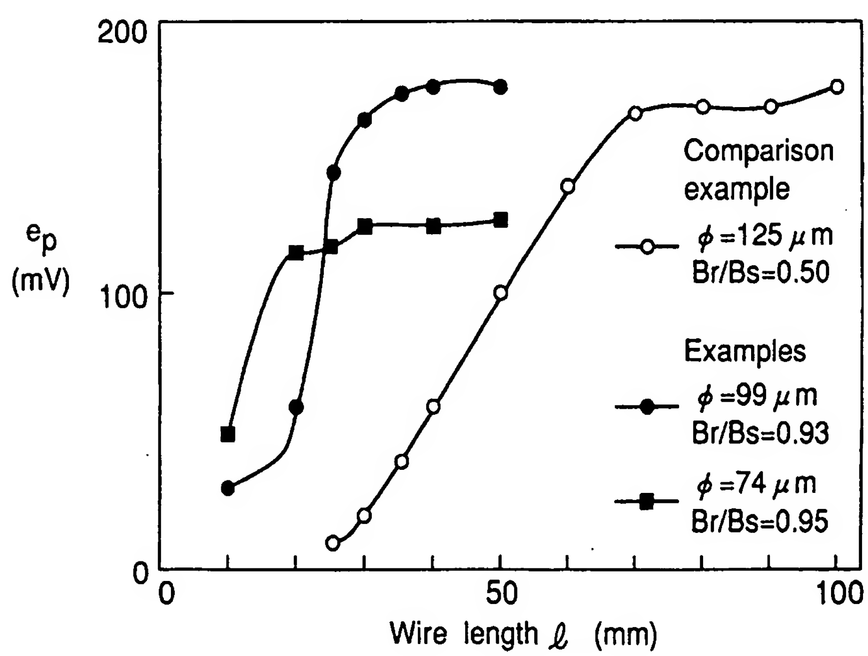

200
100
0
ep
(mV)
0
50
100
Wire length ℓ (mm)
Comparison example
ϕ =125 μm
Br/Bs=0.50
Examples
ϕ =99 μm
Br/Bs=0.93
ϕ =74 μm
Br/Bs=0.95

Fig.4

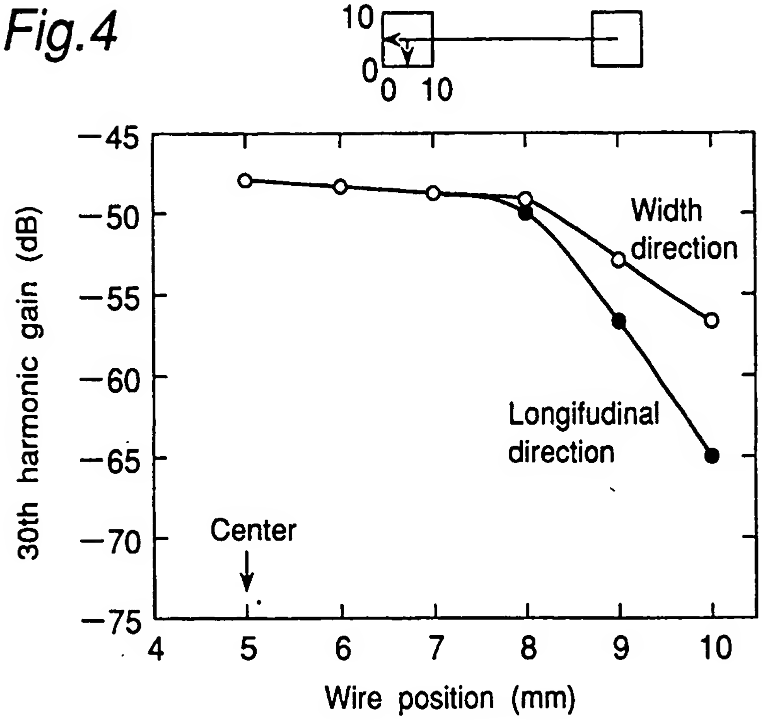

10
0
0 10
-45
-50
-55
-60
-65
-70
-75
30th harmonic gain (dB)
Width direction
Longifudinal direction
Center
4 5 6 7 8 9 10
Wire position (mm)

Fig.5

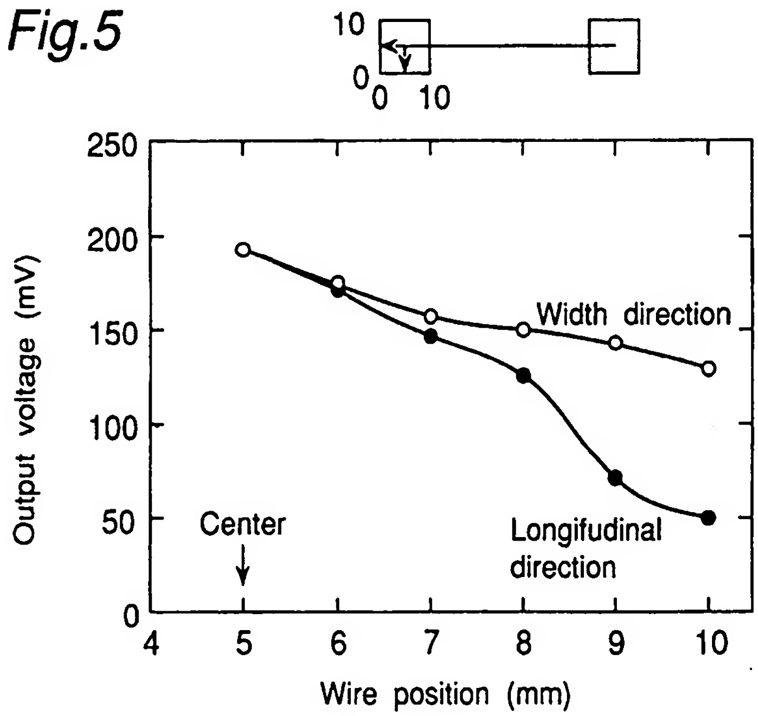

10
0
0 10
250
200
150
100
50
0
Output voltage (mV)
Width direction
Longifudinal direction
Center
4 5 6 7 8 9 10
Wire position (mm)

Fig.6

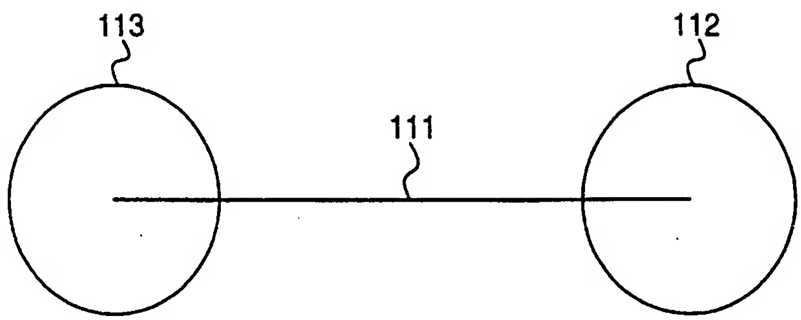


Fig.7